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GB 2202772 A

GB 2118078 A

GB 1377042 A

GB 1109416 A

GB 0366655 A

GB 0323445 A

EP 0343095 A1

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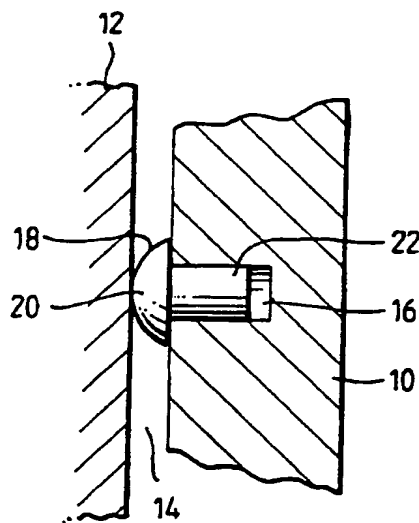
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(54) improvements in investment casting using chaplets

(57) In an investment casting process including the known steps of injecting a molten wax into a die, alloying the wax to solidify, removing the die, investing the wax with ceramic, firing the ceramic and removing the wax so as to provide a ceramic mould, and casting a molten material into the mould and apparatus including a ceramic core the shape and size of the cavity to be provided in the blade, a removable wax impression die surrounding and spaced from the core member so that the space between the die and the core member is the shape and size of the blade, there is provided a number of chaplets 18 adapted and arranged to support and locate the core in relation to the ceramic mould by point contact abutment with an adjacent mould surface. The chaplets are preferably formed of platinum.

Fig.1.



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Fig.1.

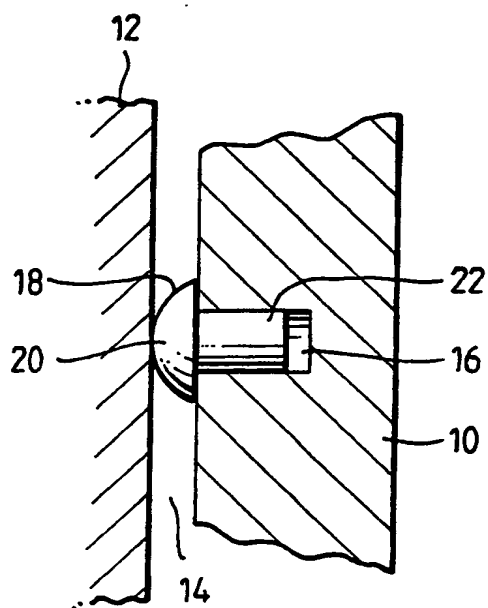
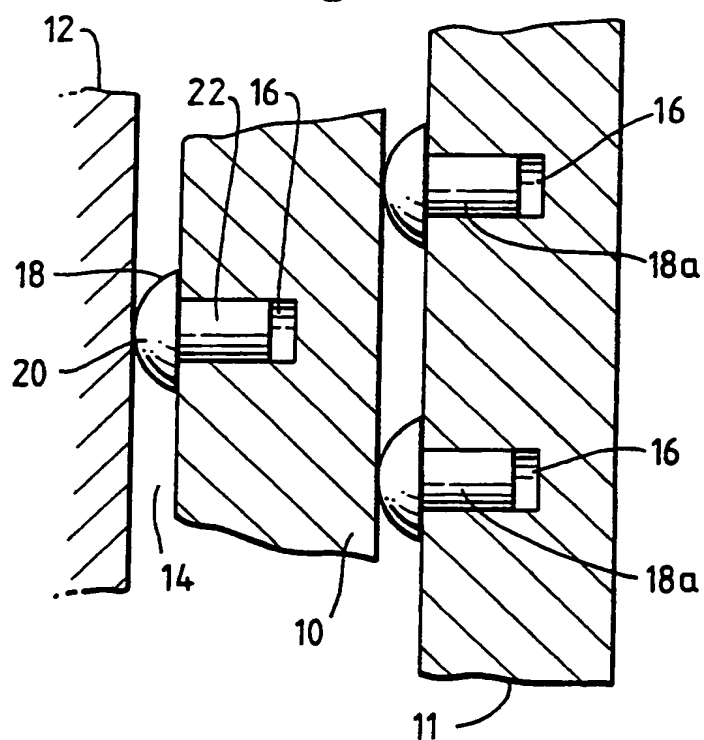


Fig.2.



IMPROVEMENTS IN OR RELATING TO INVESTMENT CASTING

This invention concerns improvements in or relating to investment casting, and in particular to precision investment casting of a metal or alloy component having an internal cavity.

Turbine blades in high performance gas turbine engines, particularly in those engines used to power aircraft, need to be able to withstand high temperatures. These temperatures may be higher than the melting point of the material of the blade, and this situation is addressed by cooling the surface of the blade by means of a stream of cool air emanating from an interior cavity of the blade through carefully designed and spaced apertures communicating with the surface.

The interior cavity is usually made by casting the blade round a ceramic core. Such a ceramic core has a silica base formulation which is sintered at approximately 1100°C and is designed to give good hot strength for dimensional control. The silica base of the ceramic also enables the core subsequently to be leached from the casting by means of a caustic alkali solution.

However, a problem arises when such cores are used in the casting of directionally solidified or single crystal alloys. These alloys are typical of the new generation of nickel-based superalloys now used in the manufacture of high performance blades. The problem is that the casting temperature is about 400°C higher than the sintering temperature, and the core is accordingly subject during casting to a substantially higher temperature than that at which it was sintered. The

core is therefore liable to distortion during the temperature changes of the casting process.

In the present established casting process a ceramic core is positioned within a blade shaped die by means of chaplets made of wax or other low melting point material. These chaplets extend from the core to the interior surface of the die. Wax is then injected into the cavity between the die and the core and is allowed to solidify. When the wax has solidified the die is removed and further chaplets comprising cylindrical platinum pins are posted through the wax to the surface of the core. The wax is then invested with a suitable thickness of ceramic slurry to provide a ceramic mould. the platinum chaplet pins extend from the surface of the core into the investment mould.

After the requisite thickness of investment coating has been applied the mould is heated so as to fire the investment coating and melt out the wax together with the original wax chaplets. The core is therefore now supported within the investment mould by the platinum chaplet pins which extend from the core into the mould. The casting of the alloy into the cavity between the investment mould and the core is then done. The mould is subsequently removed when the alloy has solidified.

It will be appreciated that there is a major disadvantage in that the platinum chaplet pins extend to the surface of the resulting casting, rendering it necessary to carry out extensive dressing of the casting to remove the projecting portions of the pins and correct the external profile. The portions of the platinum pins within the casting will have dissolved in the superalloy. In practice, platinum is not known to adversely affect the properties of the superalloy.

At a convenient stage in the process the ceramic core is leached out of the casting in the manner indicated above, to provide the required internal cavity.

A process which avoids the surface dressing requirements of the established prior art process is disclosed in UK patent GB 2118078. In this process the metal pins are replaced by chaplets which abut the mould cavity surface. The chaplets used are dimensioned in accordance with the desired wall thickness of the article to be cast, and configured in accordance with line or surface abutment at the mould cavity interface. Because the chaplets are contained entirely within the mould cavity no surface extensions are produced.

From a review of this prior art it will be appreciated, however, that the chaplets proposed are not entirely suitable for casting directionally solidified or single crystal alloys. When casting these alloys it is necessary to minimise the contact area between the chaplets and the mould cavity surface. If this area is too great grain growth may initiate at the abutment interface and disrupt the desired grain growth pattern. There is a tendency for this to occur when surface contact and line contact chaplets are used.

It is an object of the present invention to overcome the above disadvantages.

According to a first aspect of the present invention there is provided in an investment casting process for casting a component having at least one internal cavity, the process comprising the steps of providing at least one core member corresponding to the shape and size of the cavity, positioning the core member in a removable wax impression die, providing at least one support

member for the core, the support member being dimensioned in accordance with a desired wall dimension of the component to be cast, positioning the support member on the surface of the core so that the support member locates the core in relation to the die by point contact engagement of an adjacent wall surface, injecting a molten wax into the die, removing the wax once the die has solidified, investing the wax in ceramic, firing the ceramic and removing the wax to provide a ceramic mould, and casting a molten material into the mould.

According to a second aspect of the invention there is provided an apparatus for casting by means of an investment casting process a component having an internal cavity, the process including the known steps of injecting a molten wax into a die, allowing the wax to solidify, removing the die, investing the wax with ceramic, firing the ceramic and removing the wax to provide a ceramic mould, the apparatus comprising at least one core member corresponding to the shape and size of the cavity, a removable wax impression die surrounding and spaced from the core member so that the space between the die and the core is the shape and size of the component to be cast, and at least one core support member for locating the core in relation to the die, the support member being dimensioned in accordance with a desired wall dimension, and including a profiled abutment surface adapted for point contact engagement with an adjacent mould surface.

It will be understood that "wax" in the context of this specification means not only esters of fatty acids or mixtures of relatively high melting point hydrocarbons

that are commonly used in wax casting processes but other, easily melted, polymers that are solid at room temperature and which fulfil the same purpose as a casting wax.

It will be seen, therefore, that the present invention provides a cast component that has no externally projecting chaplets pins because the spacing member, which is in effect a chaplet pin, never extends beyond the external surface of the casting defined by the inner surface of the mould. Further, the spacing member, when it dissolves in the casting, leaves no holes.

The invention will now be described in greater detail, by way of example only, with reference to the accompanying drawings in which:

Figure 1 shows a section through a portion of an apparatus for casting an alloy component, having an internal passage, and

Figure 2 shows a similar section through apparatus for casting an alloy component having at least two internal passages, like reference numerals being used throughout.

In Figure 1 there is shown a section of a ceramic core 10 which provides an internal cavity for a gas turbine blade made from a nickel-based superalloy. Spaced from the core 10 is a section of a die 12, and the space 14 between the die and the core defines the wall of the hollow blade that is to be cast.

Provided in the core 10 is a hole 16 which opens into the space 14. A platinum chaplet 18 is provided as a spacing member between the core 10 and the die 12. The

chapl t 18 is mushroom-shaped, having a dome-shaped head 20 extending into the space 14 and an integral spigot pin 22 extending from the underside of the head as a close fit into the hole 16 so as to locate the chaplet in the hole and maintain the chaplet in a fixed position in relation to the core 10.

The apex of the head 20 abuts the inner face of the die 12, making point contact therewith, and the base of the head abuts the outer surface of the core 10 around the periphery of the hole 16. It is convenient to have the base of the head 20 conform to the surface of the core 10 in the vicinity of the hole 16 so as to enable good contact between the head and the core, and help maintain the stability of the head in relation to the core.

In the casting of a hollow gas turbine blade using the apparatus of the invention, the die 12, a number of platinum chaplets 18, together with the ceramic core 10, which is provided with a number of holes 16 corresponding to the chaplets, are set up as shown in Figure 1. The chaplets 18 are sized and positioned in relation to the core 10 so as to ensure that the thickness of the blade wall (as defined by the space 14) meets required blade design parameters. Thus, the wall section of the final casting can be accurately controlled.

Molten casting wax is then injected into the space 14, and allowed to cool, whereupon the die 12 is removed. The solidified wax, which now occupies the space 14, is then invested with one or more layers of a ceramic slip, which is then fired to produce a ceramic mould surrounding the core 10 and spaced therefrom by the chaplets 18. During the firing, the wax will have



volatized, but the platinum chaplets 18 will remain intact.

Molten nickel-based alloy is then poured into the space 14 between the mould and the core 10 and allowed to cool and solidify. During this process the head 20 of the platinum chaplet 18 will dissolve in the alloy. Since the chaplets 18 of the invention merely abut but do not penetrate the mould, it will be seen that the resulting casting has no external protrusions requiring removal that are attributable to the chaplets. On removal of the core 10 from the interior of the cast blade, by known caustic alkali leaching methods, or otherwise, it will be appreciated that there may be interior protrusions due to the pins 22 which were located in the holes 16 in the core, but these protrusions do not have any significant effect on the passage of cooling air through the blade.

Further, the complete dissolution of the platinum chaplets in the alloy of the blade ensures that no unwanted residual holes are left in the wall of the blade. It is also found, in practice, that the relatively small quantity of platinum used for the chaplets has no significant adverse effect on the metallurgical, physical and chemical properties of the nickel-based superalloy used for high performance gas turbine engines, and does not induce recrystallisation sites in the surface of single crystal castings.

It will be understood that the chaplets may be made from materials other than platinum, provided they meet the requirements that they do not melt during the wax casting stage, at least partially dissolve in the casting metal, and have no adverse effect on it. Such materials contemplated for use in the invention with

nickel-based superalloys are elements in Group VIII of the Periodic Table and having an atomic number in the range 44 to 78 inclusive, ie ruthenium, rhodium, palladium, osmium, iridium, and platinum. The chaplet material will be chosen to match the characteristics of the particular casting alloy being used, and combinations of elements may be used.

It is not necessary for the chaplets to completely dissolve (although in many instances complete dissolution will be the preferred option), provided that incomplete dissolution does not adversely affect the performance of the component.

It is also envisaged that chaplets of the present invention could be used to separate adjacent cores when casting multicore blades. In Figure 2, for example, a second ceramic core 11 is positioned adjacent the first core 10 to provide an additional cavity in the cast component. The two cores are separated by a chaplet or series of chaplets 18a in much the same way as the core 10 and die 12 in Figure 1. In an identical manner to the chaplets 18, the chaplets 18a maintain a predetermined distance between the separated cores throughout the casting process.

It is seen, therefore, that the invention provides a means for supporting ceramic cores in a directionally solidified or single crystal superalloy casting without the need to remove surface pins, does not induce recrystallisation sites, accurately controls the wall section of the castings, does not introduce harmful impurities in cast superalloys, and utilises a common support for ceramic cores throughout all the critical investment casting process operations.

Th principles of the invention may be applied equally to the investment casting of hollow articles other than hollow gas turbine blades, and made of materials other than nickel-based alloys. Ferrous and non-ferrous alloys are contemplated, as well as castable non-metallic materials such as polymers. In this latter instance the chaplets may be made of polymeric materials which have no adverse effects on the cast polymer. The chaplets of the invention can also be used to maintain internal wall sections between chamber of ceramic cores, and also when an external surface of a casting is created by a ceramic preform and not by an investment shell.

CLAIMS

- 1 An investment casting process for casting a component having at least one internal cavity, the process comprising the steps of providing at least one core member corresponding to the shape and size of the cavity, positioning the core member in a removable wax impression die, providing at least one support member for the core, the support member being dimensioned in accordance with a desired wall dimension of the component to be cast, positioning the support member on the surface of the core so that the support member locates the core in relation to the die by point contact engagement of an adjacent wall surface, injecting a molten wax into the die, removing the wax once the die has solidified, investing the wax in ceramic, firing the ceramic and removing the wax to provide a ceramic mould, and casting a molten material into the mould.
- 2 A process as claimed in claim 1 wherein the support member is domed-shaped having a base abutting the core member and an apex engaging a point on the adjacent wall surface.
- 3 A process as claimed in claim 1 or 2 wherein the support member is provided with an internal spigot adapted to locate in a corresponding aperture in the core member, thereby to retain the support member in a fixed location in relation to the core member.
- 4 A process as claimed in any preceding claim wherein the support member is made from a material that

remains solid when immersed in molten wax but is at least partially soluble in the molten casting material.

- 5 A process as claimed in claim 4 wherein the support member is made from a material that does not affect to any significant extent the properties of the casting material.
- 6 A process as claimed in claim 1 wherein, when the casting material is a nickel-based alloy, the support member has as its principal constituent one or more elements selected from Group VIII of the Periodic Table and having an atomic number in the range 44 to 78.
- 7 A process as claimed in claim 6 wherein the principal constituent of the support member is platinum.
- 8 A process as claimed in claim 7 wherein the support member is made entirely of platinum.
- 9 A process as claimed in any preceding claim wherein the core member is made from a ceramic that is capable of being leached by caustic alkali.
- 10 A process as claimed in claim 1 wherein the adjacent wall surface corresponds to an external surface of the component to be cast.
- 11 A process as claimed in claim 1 wherein the adjacent wall surface corresponds to an internal surface of the component to be cast.

- 12 A process as claimed in claim 11 wherein separate cores are located within the mould, and the adjacent wall surface corresponds to a surface of an adjacent core member.
- 13 An apparatus for casting by means of an investment casting process a component having an internal cavity, the process including the known steps of injecting a molten wax into a die, allowing the wax to solidify, removing the die, investing the wax with ceramic, firing the ceramic and removing the wax to provide a ceramic mould, the apparatus comprising at least one core member corresponding to the shape and size of the cavity, a removable wax impression die surrounding and spaced from the core member so that the space between the die and the core is the shape and size of the component to be cast, and at least one core support member for locating the core in relation to the die, the support member being dimensioned in accordance with a desired wall dimension, and including a profiled abutment surface adapted for point contact engagement with an adjacent mould surface.
- 14 An apparatus as claimed in claim 13 wherein the support member is dome-shaped, the apex of the dome being adapted to abut an adjacent mould surface spaced from the core, and the base of the dome being adapted to abut the surface of the core member.
- 15 An apparatus as claimed in claim 13 wherein the support member is provided with an internal spigot adapted to locate in a corresponding aperture defined in the core member, thereby to retain the

support member in a fixed location in relation to the core member.

- 16 An apparatus as claimed in claim 13 wherein the support member is made from a material that remains solid when immersed in molten wax but is at least partially soluble in the molten casting material.
- 17 An apparatus as claimed in claim 16 wherein the support member is made from a material that does not affect to any significant extent the properties of the casting material.
- 18 An apparatus as claimed in claim 13 wherein, when the casting material is a nickel-based alloy, the support member has as its principal constituent one or more elements selected from Group VIII of the Periodic Table and having an atomic number in the range 44 to 78.
- 19 An apparatus as claimed in claim 18 wherein the principal constituent of the support member is platinum.
- 20 An apparatus as claimed in claim 19 wherein the support member is made entirely of platinum.
- 21 An apparatus as claimed in any preceding claim wherein the core member is made from a ceramic that is capable of being leached by caustic alkali.
- 22 An apparatus for casting by means of an investment casting process a component having an internal cavity, the apparatus being substantially as hereinbefore described with reference to the accompanying drawings.

- 23 An investment casting process substantially as hereinbefore described with reference to the accompanying drawings.



**Patents Act 1977**  
**Examiner's report to the Comptroller under Section 17**  
**(The Search report)**

Application number  
GB 9416937.2

15

**Relevant Technical Fields**

- (i) UK Cl (Ed.M) B3F (FMH, FMG, FMA, FMB); B5A (ALA, ALX, AB12)
- (ii) Int Cl (Ed.5) B22C (7/02, 9/04, 9/06, 9/10, 21/12, 21/14); B29C (39/26, 33/30, 33/76)

Search Examiner  
P G BEDDOE

Date of completion of Search  
5 OCTOBER 1994

**Databases (see below)**

(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

Documents considered relevant following a search in respect of Claims :-  
1 TO 23

(ii) ONLINE DATABASE: WPI

**Categories of documents**

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- A:** Document indicating technological background and/or state of the art.
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Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2202772 A	(AE PLC) see especially page 3 line 19 to page 4 line 7	1, 4, 5, 6, 9, 13, 16, 17, 18, 21
X	GB 2118078 A	(HOWMET) see especially Figures 7, 8	1, 4, 5, 6, 9, 13, 16, 17, 18, 21
X	GB 1377042	(SHERWOOD) see especially page 5 lines 77 to 93	1, 4, 5, 6, 9, 13, 16, 17, 18, 21
X	GB 1109416	(ASHWORTH) see especially Claim 1 and figure	1, 4, 5, 6, 9, 13, 16, 17, 18, 21
X	GB 366655	(LAING) see especially Figure 3; page 2 lines 68 to 84	1, 4, 5, 6, 9, 13, 16, 17, 18, 21
X	GB 323445	(SONNET) see especially Claim 1 and Figures 1a, 1c	1, 4, 5, 6, 9, 13, 16, 17, 18, 21

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## Continuation page

Category	Identity of document and relevant passages	Relevant to claim(s)
X	EP 0343095 A1 (SCHMIDT) see especially Figures 1, 2 and Claim 1	1, 4, 5, 6, 9, 13, 16, 17, 18, 21